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NIAGARA AS A TIMEPIECE.

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NIAGARA FALLS IN HISTORY.—Guided by an Indian chief, La Salle and Hennepin visited Niagara Falls in 1678, but it was not until 1697 that Hennepin published his picture of the cataracts, which, in spite of the rude perspective of two centuries ago and the prominence of the *voyageurs*, is famous for having been the first pictorial representation of the falls of Niagara (Fig. 1).

The existence of the falls was known a century and a half earlier than Hennepin's narrative through reports of the Indians to Jacques Cartier (1535). In the early part of the seventeenth century, Champlain and several Jesuit fathers mention the cataract, which was mapped by two of them under the name of "Onigara." Reproductions of Hennepin's picture were frequently made, but there appear to be no fairly good drawings of the falls preserved older than that of Lieutenant William Pierie, of date of 1768 (Fig. 2).

The scenery and even the geology of the Niagara district have been known for nearly half a century, and hundreds and perhaps thousands of papers have been published upon the falls of Niagara. Yet "problems settled in a rough and ready way by rude men absorbed in action demand renewed attention and show themselves to be unread riddles . . . when men have time to think." Even now it is scarcely fifteen years since the history of the falls began to be known.

If we look at a picture of the Falls of Montmorency, near Quebec (Fig. 3), cascading about two hundred and seventy-five feet over the wall of the St. Lawrence almost directly into the river

itself, without flowing through any cañon whatever, and then glance at the gorge of Niagara River, seven miles long, of which only a fragment can be seen in a picture (Fig. 4), the striking difference awakens inquiry. The cause does not lie in either the magnitude of the streams or in the character of the rocks; it is a question of the difference of the age, for Niagara Falls once cascaded from the edge of the mountain wall (Fig. 16) directly into the expanded waters of the Ontario basin just as the Montmorency stream is pouring into the St. Lawrence River to-day.

EARLY ESTIMATES OF THE AGE OF NIAGARA FALLS.—All attempts at reducing geological time to solar years meet with great difficulties, yet Niagara Falls have been used as a chronometer as

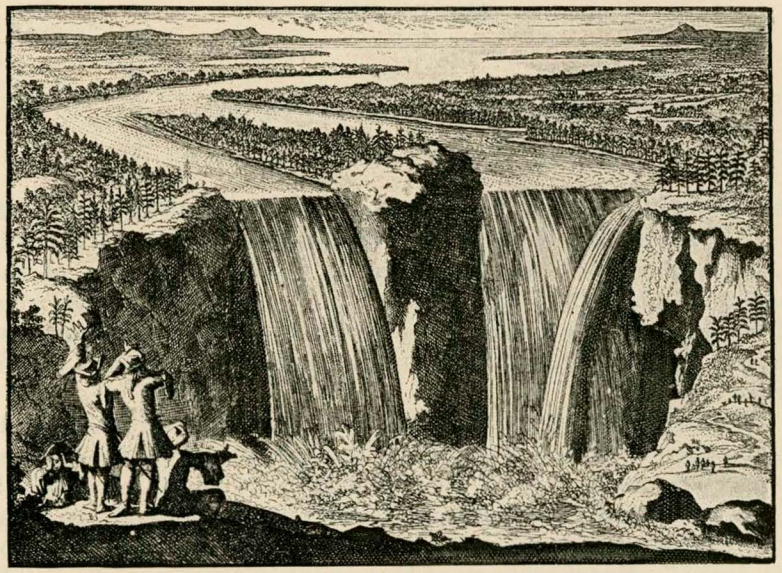

FIG. 1.—FACSIMILE OF A VIEW OF NIAGARA FALLS BY FATHER HENNEPIN.

frequently as any other natural phenomenon, and indeed Niagara is perhaps the best measurer that we have. Even at an early date, when the antiquity of the earth was not a popular doctrine, Andrew Ellicott (in 1790) divided the length of the gorge by the supposed rate of recession of the falls, and assigned fifty-five thousand years as the age of the cataract. Forty years later Bakewell reduced the time to twelve thousand years, and a few years afterward Lyell's estimate of thirty-six thousand years became popular and remained so until about fifteen years ago. This method of dividing the length of the chasm by the rate of recession was correct as far as it went, but even the rate was not then known.

METHOD OF COMPUTING THE AGE OF THE FALLS.—Many years

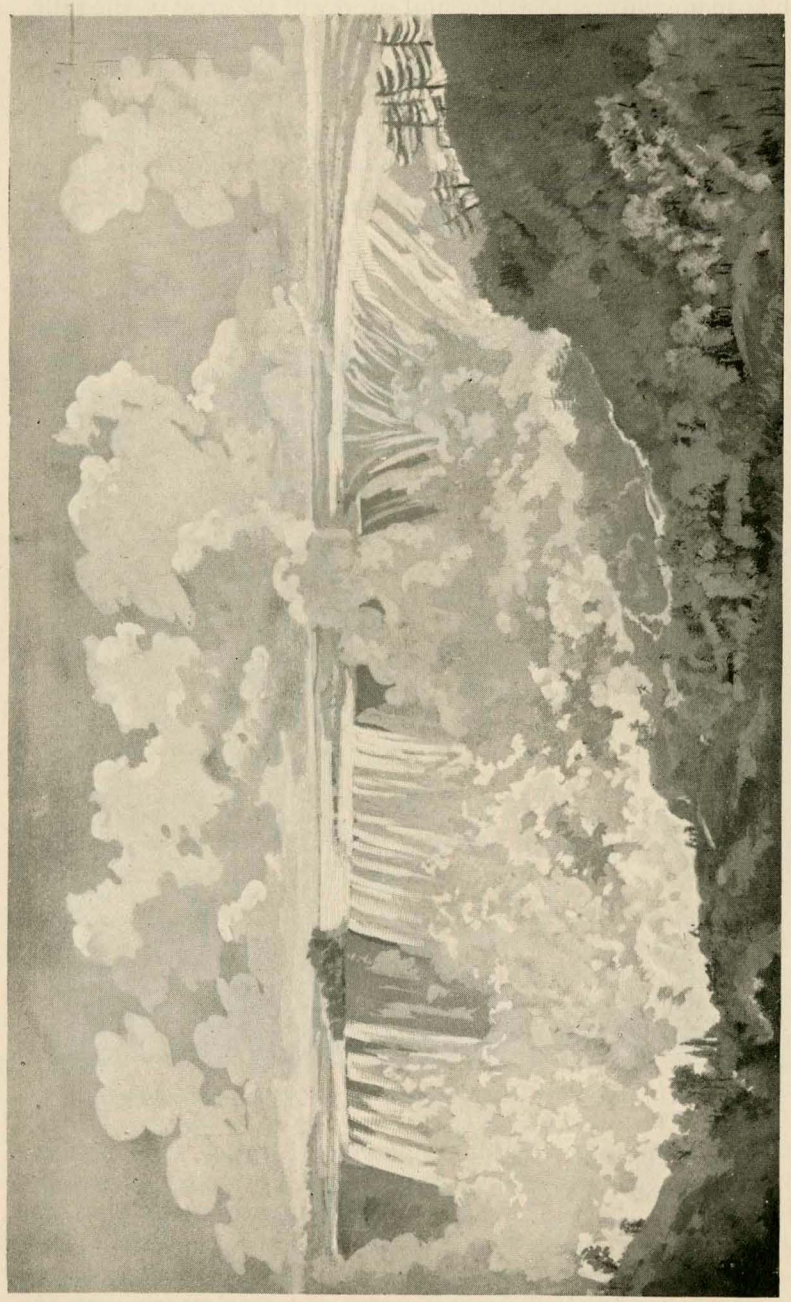

FIG. 2.—CATARACT OF NIAGARA FALLS, WITH THE ADJACENT COUNTRY. (From a drawing on the spot by Lieutenant William Pierie, of the British Artillery, 1768.) This picture was kindly furnished by Peter A. Porter, Esq., of Niagara Falls.

ago Prof. James Hall laid the foundation of all future calculations when he made the first instrumental survey of the crest of the falls. The changes in the crest have been measured three times since, and from these surveys the mean recession for nearly half a century is now known and has been found to be much more rapid than was formerly supposed. If the whole history of the falls of Niagara were thus told, then it would appear that their age is

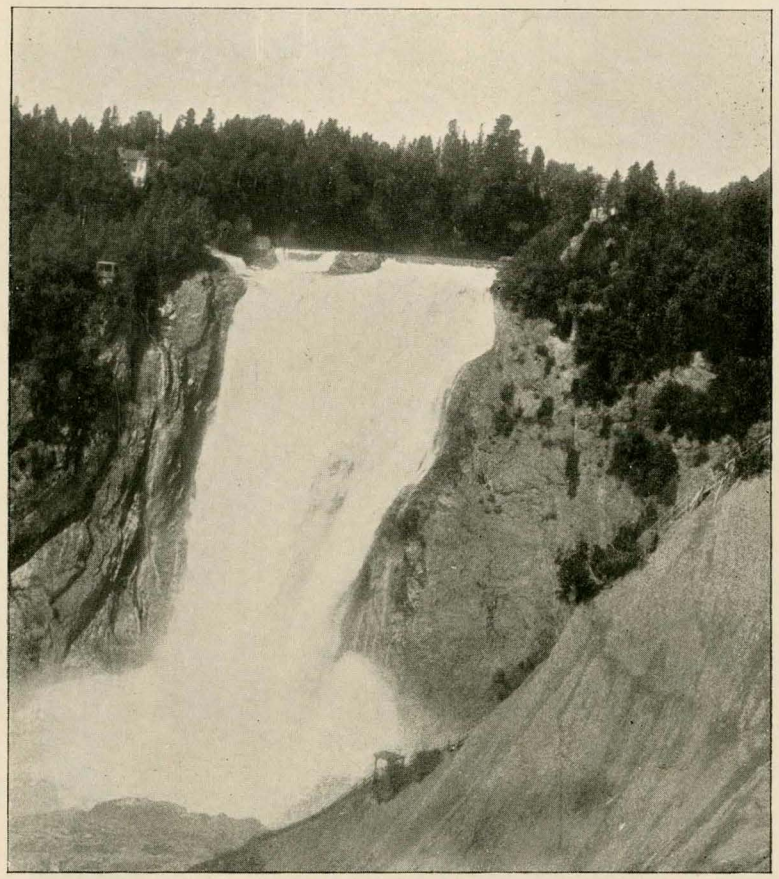

FIG. 3.—FALLS OF MONTMORENCY. (About 275 feet high.)

about nine thousand or ten thousand years. Indeed, some writers, among others Mr. Gilbert, took this reduced estimate and minimized it to seven thousand years, not knowing or overlooking the history of the river which tells of the changing conditions; but these views he now abandons. The chronometer needed correction. During a term of several years of actual work, but extended through a decade and a half, for the investigations were often blocked with difficulties, the writer has been able to decipher

many phases in the history of the lakes in their bearing upon the growth of the falls, and only after that field work could any attempts at computing the age of the falls be made. A few of the necessary discoveries may be referred to: (*a*) The Niagara River did not drain the Erie basin in ancient times, and consequently there was no ancient river channel ready for the modern stream. (*b*) All the features of the chasm are modern, and only very slightly modified by the older forms of land sculpturing. (*c*) After the birth of the river, Huron and the sister lakes did not empty into the Niagara drainage until comparatively recent times, and therefore, on account of draining only the Erie basin, the volume of the water cascading over the early falls was small. (*d*) Then the descent of the river varied greatly, being for very long ages less than now, and again temporarily much greater. (The observation of the greater height of the falls was made by Prof. G. K. Gilbert, who has followed the writer in the other important points named.) (*e*) The determination of the amount of work accomplished by the falls during each of the episodes of the river seemed the most difficult, but this has been accomplished with partial success. These things have been mentioned to show that the computation of the approximate age of the falls has been a complex question and also one of tedious delays, yet a problem that will continue to awaken interest so long as men endeavor to ascertain the antiquity of the ice age and the correlated antiquity of man. Niagara River is perhaps our best chronometer, and by applying the age of the falls to the deserted shore lines the antiquity of possibly man-inhabited river banks of distant regions and forgotten times will be discovered. Directly the determination of the age of the falls is a stepping stone to the date of the close of the ice age. Under these circumstances the investigations seem to justify the presentation of the results to the general reader, leaving to the essayist the repetitions of the other geographical or picturesque features or the pretty stories of Niagara. Even the great Lyell had no better means of ascertaining the antiquity of the falls than mere conjecture, for a long period of observation was necessary. Strangely, however, his suggestion was not far from the computations based upon our increased knowledge. This coincidence arose from the occurrence of compensating errors, those corrected on the side of reduction of time used alone giving results further from the truth than the mere conjecture, as the varying conditions of the river which increase its antiquity were not known.

SOME MODERN AND ANCIENT FEATURES OF THE NIAGARA DISTRICT.—The map of the Niagara district (Fig. 5) shows a table-land a few feet above the surface of Lake Erie, and extending northward for nineteen miles to the edge of the Niagara

FIG. 4.—THE NIAGARA GORGE BELOW THE WHIRLPOOL.

escarpment, where there is a sudden descent of two hundred and forty feet to the lower plain, that gradually slopes for eight miles farther to the present shores of Lake Ontario, whose waters are three hundred and twenty-six feet below the surface of Lake Erie.

The features of the plain which have a bearing upon the development of the Niagara River are, a low ridge crossing the river just north of the outlet of Lake Erie; a comparatively level plain underlaid by soft rocks, extending thence to near the head of the rapids above the falls, north of which, to the brow of the escarpment, the country rests upon hard limestones, with underlying strata of soft shales and occasional layers of more persisting rocks. These softer shales form the foundation of the country between the end of the gorge at the brow of the mountain near Queens-

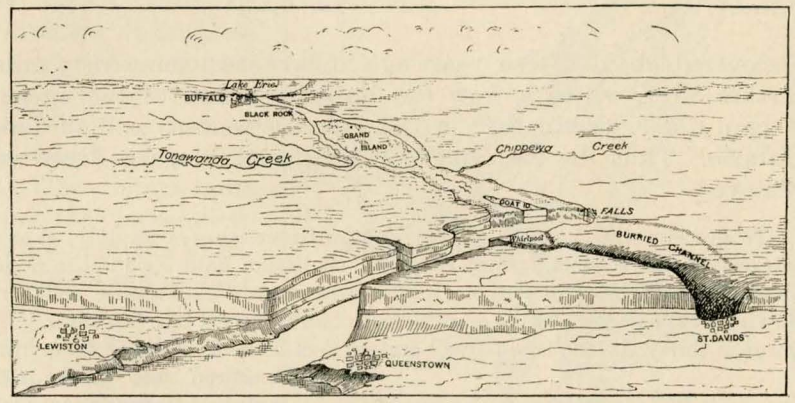

FIG. 5.—BIRD'S-EYE VIEW OF THE NIAGARA DISTRICT (Pohlman). The buried channel or valley from the falls to the edge of the mountain at St. Davids is about a mile and a half broad, but it is not anywhere nearly as deep as the Niagara gorge.

ton (and Lewiston) and Lake Ontario. The work of the river has been to remove the soft rocks and undermine the thick and hard capping limestones. The chasm of the Niagara River is simply chiseled out of an elevated table-land, whose surface is a remarkably level plain, covered with towns, villages, and farms, extending apparently without a break until one is surprised at coming suddenly upon the brink of an abyss, without meeting with the sloping features which constitute the usual approaches to deep valleys. The feature of the gorge with unbroken perpendicular walls is shown in Figs. 6 and 7, which are characteristic forms of modern cañons. If the valley were of great antiquity it should have been two miles or more in width, in place of a gorge of a quarter of a mile wide, and it should have had scarcely any fragments of perpendicular walls standing. Indeed, an old valley, buried beneath some ninety feet of drift, does cross the course

of the modern river in the region of the falls themselves, but this is a mile and a half wide. Its section is shown beneath the drift in Fig. 8.

Indeed, there was no ancient outlet of the Erie basin in the vicinity of Niagara River, but the ancient drainage course was

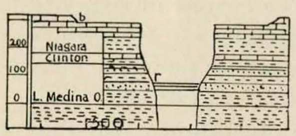

Fig. 6.—Section across the Narrows just North of the Railway Bridges (*dd*, Fig. 9). *b*, Original bank of the river; *r*, surface of the river; L O, level of lake; floor of cañon eighty feet below lake level.

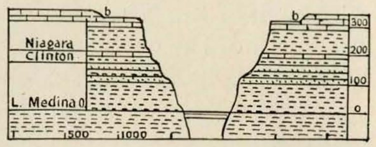

Fig. 7.—Section Half a Mile from the End of the Cañon (*gg*, Fig. 9). *bb*, Terraces of river at the original level; L O, level of Lake Ontario; bottom of river about eighty feet below the surface of Lake Ontario.

discovered about fifteen years ago to have been some forty miles farther west, where is now the buried channel of the ancient Erigan River, terminating in the extreme western end of Lake Ontario. Thus the necessity of a preglacial Niagara River was removed.

To describe the features of the Niagara River more accurately, so as to interest special readers, it may be added that from Lake Erie to the rapids above the falls the river is from half a mile to more than a mile wide, and flowing at the surface of the country with banks only a few feet high. The gorge is thirty-six thousand five hundred feet long and varies from nine hundred feet to fourteen hundred feet wide at the top, and it is three hundred and forty feet deep near the outlet. The width of the river itself at the narrows is only three hundred feet and four hundred at outlet of whirlpool, although elsewhere much broader. The rubbish in the chasm forms loose heaps of broken rock, which is constantly falling from the sides, and building up sloping banks along the water's edge, where the rains and river are constantly washing them away, and thus the cañon is slowly being widened into a common form of an old valley. The river, both near the foot of the falls and seven miles below, at the outlet of the gorge, is nearly one hundred feet in depth, descends fifty feet by the rapids above the falls, which leaps one hundred and fifty-eight feet into the abyss, from which it further descends another hundred and ten feet by the rapids below the falls. These features are

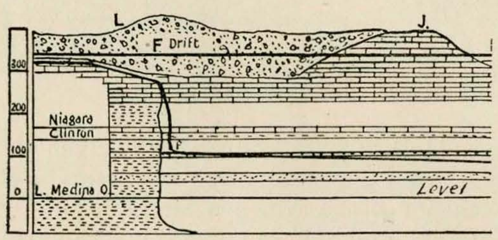

Fig. 8.—Section at the Site of the Falls, showing the Transverse buried Tonawanda Valley, F, cut out of limestones for breadth of a mile and a half and depth of ninety feet; rectangular shading represents the Niagara limestones; L O, level of Lake Ontario; F, foot of falls.

shown on the map of the gorge (Fig. 9), and in the longitudinal section in Fig. 16.

The Whirlpool and its Ravine.—The elbow of the Niagara gorge at the whirlpool has given rise to much speculation and has led to great confusion. Fifty years ago Sir Charles Lyell supposed that it indicated an ancient course of the river itself, which extended thence to the St. Davids' Valley, about four or five miles distant, although the country forms a level floor which told of no buried channel (see Fig. 5). This mistake arose from the perpendicular walls of the whirlpool basin, without the necessity of sloping sides for ancient valleys being then perfectly known, and without the author evidently going through the ravine where rocks were exposed. The serious feature of the mistake was that it led to the supposition that perhaps much of the gorge above the whirlpool was older than that portion below, and, becoming filled with drift, the river had only the drift filling to remove in modern times. This idea caused Dr. Pohlman to reduce the age of the falls to three thousand years. But almost universally the error of a deep preglacial

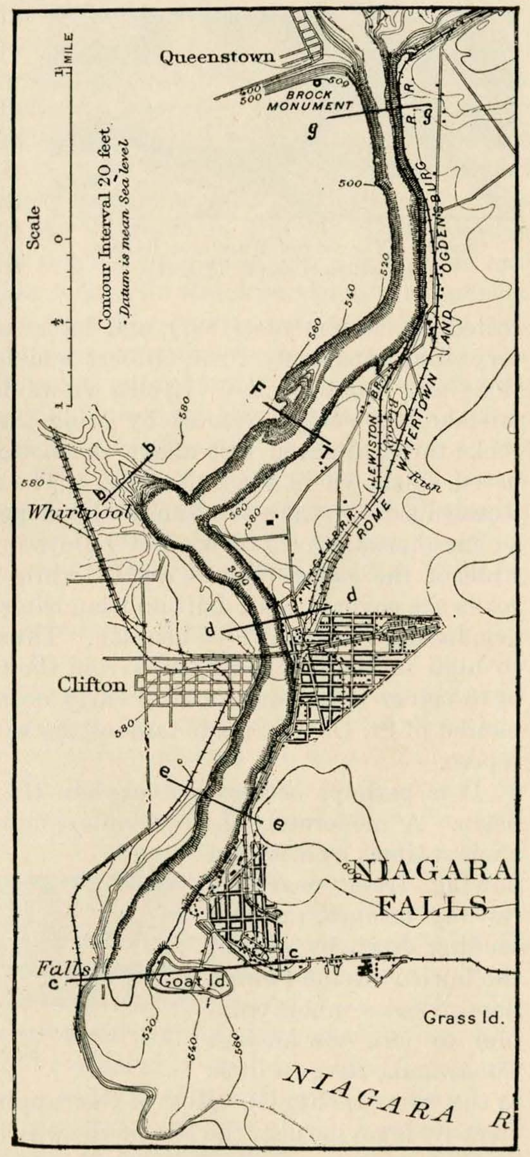

Fig. 9.—Map of the Niagara Gorge (United States Lake Survey), showing its Variable Width and Cross-sections.

gorge was followed, as most authors absorb the work of others without verifying it throughout. In this matter even the present writer, in the beginning of these investigations (1881), partially accepted Lyell's idea, but distinctly showed that the buried ravine from the whirlpool was not preglacial but probably that of a small interglacial stream, and not that of the Niagara River. Prof. Claypole found rocks in the ravine, and then the writer immediately corrected his statements (1887), and later explained the whole history; but apparently Prof. Gilbert had forgotten these observations and went back to Lyell's views in their entirety. The mistake was easily corrected by going through the ravine, where rocks three hundred feet above the bottom of the river are exposed, as shown in Figs. 10 and 11. The exposed rocks along the western side of the ravine show the slope as in section, which is a characteristic form of ancient valleys in contrast to the vertical walls of the cañon (Figs. 6 and 7), while on the eastern side the rocks are covered with drift and landslides, but at the same time demanding sloping walls beneath. Thus the presence of rocks so high in the ravine removes from the calculations of the work of the river the obstructions of early observers, and relegates the hamlet of St. Davids, made famous the world over, to its peaceful repose.

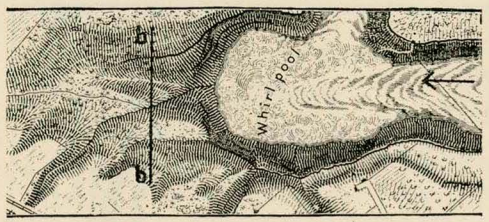

FIG. 10.—MAP OF THE WHIRLPOOL RAVINE.
bb, Position of section (Fig. 11).

It is perhaps necessary to explain the form of the whirlpool basin. A moderately shallow valley, now buried, was formed in ancient times by a stream flowing from near the railway bridges, and extending down by way of the buried ravine (which has given so much trouble) to join the ancient Tonawanda River a little to the west (see Fig. 5). Most of the capping limestones in the ancient little ravine near the site of the whirlpool had been removed, leaving at or near the surface only soft, shaly rocks, yet three hundred feet above the bottom of the river. When the modern falls had receded so as to reach the edge of the little buried valley, it found the surface occupied by loose materials which for a short distance the river easily swept out, and thus by the circulating currents was the form of the basin started, and afterward deepened in the soft shales. The rocks at the end of the basin are always obscured by the landslides of the overlying drift materials.

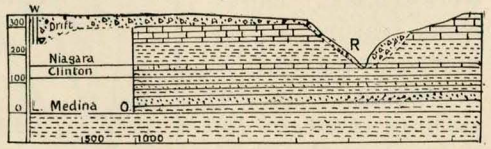

FIG. 11.—SECTION ACROSS THE WHIRLPOOL RAVINE: located at *bb* (Fig. 10).

NIAGARA FALLS CROSSING THE ANCIENT AND BURIED TONAWANDA RIVER.—Reference has been made to the ancient buried valley westward of the Niagara. In olden days the rains, rills, and rivulets were everywhere acting upon the surface of the land and producing broad, flattened features which are characteristic of old topography. Through such a valley flowed the ancient Tonawanda River (partially recognized by Dr. J. Pohlman), draining the Niagara district (as indicated in Fig. 5). This valley in the vicinity of the falls was about a mile and a half wide and ninety feet lower than the rocky rim which bordered the northern side (see Fig. 8), which barrier is now exposed between the railway and the carriage bridges over the river. In wells this ancient valley has been found to extend in the direction of the St. Davids Valley (Fig. 5), which is comparable in size to it, in place of turning off at right angles, as does the modern river at the location of the falls. This ancient Tonawanda River never drained the Erie basin, and when it afterward became filled with drift it did not determine the character of the modern river, except to give rise to the magnificent rapids above the falls (as shown in Fig. 17).

EFFECTS OF THE DEPRESSIONS OF THE ANCIENT SURFACE AND THE GEOLOGICAL STRUCTURE UPON THE RECESSION OF THE FALLS.—The partial scooping out of the superficial limestones in the vicinity of the falls and at the whirlpool is the only important feature which has noticeably affected the excavation of the modern river channel, and this only to a very small extent, for the ancient depressions were filled with the rubbish of the drift period, which loose material was protected from being carried away by the flowing currents; and even after the last barrier of rock had been removed by the retreat of the falls, the river had nearly as much work as ever to do, for the recession of the falls is by the undermining of the capping limestones, and not on account of their being worn away by the river to an appreciable extent. Furthermore, the regularity of the recession has been largely maintained by the remarkably uniform character of the beds of rocks, which for a considerable portion of the length of the cañon are almost horizontal, and only at the lower end do they dip as much as fifteen or twenty feet in a mile. Now all these explanations mean that the character of the country and the geological formations would not cause any great variation in the rate of the recession of the falls, but those changes were due to the other and farther reaching causes.

Modern Recession of the Falls.—The modern rate of retreat of the cataract during forty-eight years has been determined by comparing the crest of the falls, carefully mapped by four surveys—the first by Prof. James Hall in 1842 and the last by Mr.

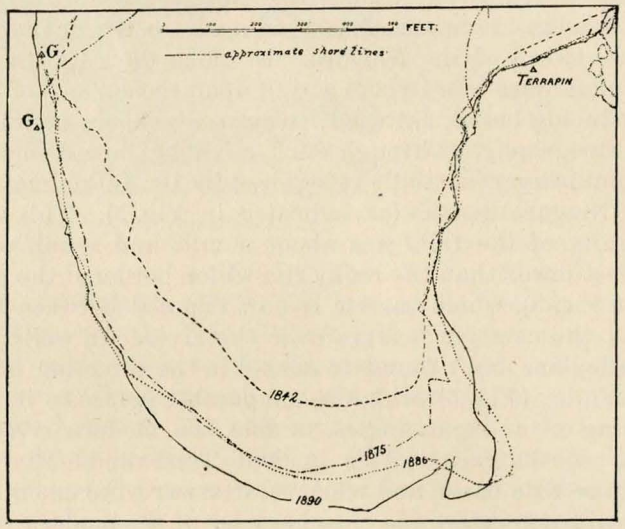

Fig. 12.—The Four Surveys of the Canadian Falls, showing the Retreat of the Cataract, in which some Inaccuracies are Apparent. (Kibbe.)

Augustus S. Kibbe in 1890. Between the times of these surveys not merely the historic Table Rock, but six acres of rocks forming the floor of the river fell away by the undermining action of the falls, and the center of the cataract moved upward for a distance of two hundred and twenty feet. From the 275,400 square feet thus removed it is found that the mean annual recession has been four feet and a sixth a year for the Canadian falls and two thirds of a foot for the American cataract. The recession is shown in Fig. 12.

The work of the falls is not uniform, for there are years of rapid central recession and slow lateral expansion, followed by even a total central rest and rapid lateral enlargement of the curve. From an approximate estimate of the variation in the amount of work due to the physical and geological structure of the district, the mean rate of recession of the falls under existing volume of water and descent of the river may perhaps be reduced to 3·75 feet a year, which factor alone would indicate the age of the cataract to be ten thousand years. But this simple story would leave out of consideration the variability of the volume of Niagara River and the descent of the cascades.

The Story of the Lakes and the Birth of Niagara Falls.—At the close of the ice age, and after the geological

broom had swept the accumulated dirt of ages from the northern country and filled up the great valleys, the lake region was covered with water; whether arms of the sea, as is probable, or as lakes, of which the barriers are not indicated, is immaterial in the history of the river, for under either condition the old shores were produced, and these we have surveyed. From them we learn the story that all the lakes formed one broad sheet named the Warren water. From time to time its surface was lowered, and at each pause new stands were formed, only to be abandoned by further sinking of the water. At last the aboriginal Warren water subsided so that it became divided in two smaller sheets—the Algonquin gulf, occupying more or less of the basins of Lakes Huron, Michigan, and Superior, and the Lundy gulf, extending over much of the Erie and the Ontario basins. With the continued lowering of the gulf, or, more correctly, the rising of the land, for no evidence of lake barriers has been found, the Lundy gulf became dismembered, forming Lake Erie, then much smaller than now, and the Iroquois gulf occupying the Ontario basin, the deserted shores of which have now an elevation much above the

Fig. 13.—View of the American Falls.

present altitude of the lake. Then Niagara Falls had their birth, and the river descended only a little more than half as great a height as to-day into the gulf (Fig. 16) which came to the mouth of the gorge. The lowering continued until the descent of the river was much greater than at present, and the shores of the lake receded not merely eight miles to the present margin of the

lake, but four miles farther. Again, the waters of Ontario were raised and the descent of the river was reduced to the present amount. Thus it is apparent that at the birth of Niagara Falls the cataract was much smaller than now, and very much resembled the size of the American Falls as shown in Fig. 13.

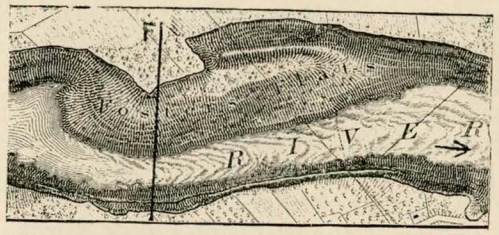

FIG. 14.—MAP OF THE GORGE AT FOSTER'S FLATS. F, Location of the cross-section (Fig. 15).

With the discovery of the history as here set forth, we had to wait several years before any clew was obtained as to how far the falls receded during each of the episodes. But at last the inquiry was partially successful; for at Foster's Flats (Fig. 14, see also Fig. 9), about two miles and a half above the mouth of the gorge, the remains of an old terrace occur (Fig. 15) at the height which shows that the falls had receded to that point before the descent of the river was greatly increased or the volume of the water enlarged to the drainage of all the upper lakes.

In this determination of the distance to which the falls had probably receded before Lake Huron drained into Lake Erie, Prof. Gilbert has followed the writer. Now, by applying the laws of the variability of erosion to the observed modern rate of recession of the falls, an approximate determination of their antiquity became possible.

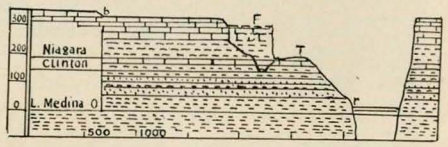

FIG. 15.—SECTION OF THE GORGE AT FOSTER'S FLATS (FT, Fig. 9). Platform (F) of the old river floor projecting into the cañon. Its section is shown in broken shading, but with ravines descending from both sides of it; T, rock terrace surmounted by huge blocks of Niagara limestones; *b*, original river terrace; *r*, surface of river; L O, surface of Lake Ontario. Bottom of river about eighty feet below the surface of the lake.

CAUSES OF FLUCTUATION IN THE VOLUME AND DESCENT OF NIAGARA RIVER.—In the survey of the deserted shores it was found that since they were formed as old water-lines they have been tilted upward toward the north and east at variable rates, from a few inches in a mile at the southwest to four or even seven feet per mile in the opposite direction. The phenomenon belongs to the consideration of the history of the lakes, but its effect was to tilt the lake basins so that the water ran over the southern rim of Lake Huron into the Niagara drainage. So, also, the tilting of the Ontario basin raised the barrier at the outlet and caused the waters to rise and flood the lower lands at the head of the lake, and shorten the Niagara River by four miles

or more, and reduce the descent of the river by eighty feet or more.

EPISODES OF THE NIAGARA RIVER AND THEIR DURATION.—At first the river flowed without falls, as shown by the old banks and terraces, for a period estimated at a thousand years. Then the waters of the lower lake began to subside, whereupon the Niagara Falls had their birth. The new cataract slowly grew in height, although characterized by temporary pauses, until the river cascaded two hundred feet from the tableland into the edge of the gulf or lake which occupied the Ontario basin, as shown in Fig. 16.

The volume of the water of Lake Erie is about one fourth that of all the upper lakes, and only this proportion of the discharge of the modern Niagara River formed the abrading agent of the falls at that early date. This general condition lasted for seventeen thousand two hundred years.* After this episode, the descent of the river was increased to four hundred and twenty feet, and the lake receded twelve miles from the foot of the mountain, and then there was a series of three cascades, the lower always gaining upon the upper on account of the softer rocks. Yet the increased amount of work to be done, even though easier than the recession

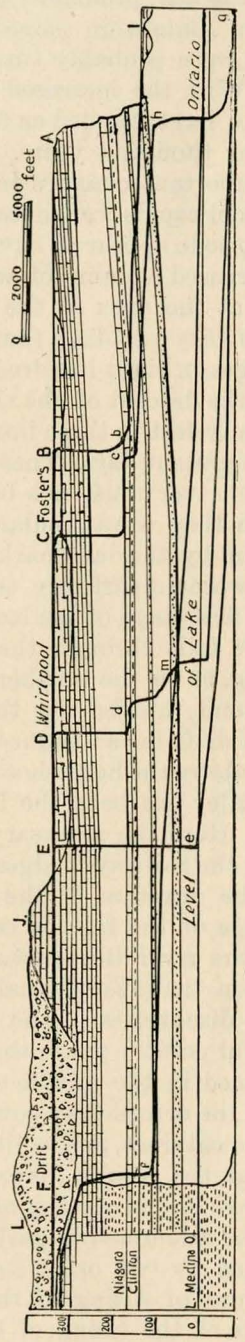

FIG. 16.—LONGITUDINAL SECTION, SHOWING THE RETREAT OF THE FALLS AND THE GEOLOGICAL STRUCTURE. A, Brow of escarpment and original site of falls; I, Iroquois beach and level of that water; B *b* I, chasm at the end of the first episode; C *c h g*, falls retreating in three cascades, but from *h* to *g* the slope was extended over a distance of twelve miles beyond the escarpment; D *d m g*, position of cataracts at the end of the second episode; E *e g*, development of gorge at the end of the third episode; F, present site of falls, and F *m g*, the modern cañon; *g*, level of the lowest stage of water in the river history; L, Lundy beach capping the drift; J, Johnson's ridge. Broken shading about whirlpool shows occurrence of drift on west bank only with rock on the eastern; block shading represents limestone; dotted, sandstone; broken lines and unshaded portion, shales. Bottom of river eighty feet below present surface of Lake Ontario, as shown in figure.

* For the methods of computation of the duration of the episodes of Niagara Falls see Duration of Niagara Falls and the History of the Great Lakes, pp. 1–126, 1895. Also see Duration of Niagara Falls, American Journal of Science, December, 1894, pp. 455–472—both works being by the writer.

of the upper cascade, prolonged the episode to six thousand years, when Foster's Flats were passed. By this time the waters of Lake Huron were probably turned into the Niagara by way of Lake Erie. With the increased magnitude of the river the falls are thought to have receded as far as the head of the whirlpool, requiring four thousand years. By the close of this stage there were some important changes in the river, as when the narrows of the whirlpool rapids were excavated, and the three cataracts of the second episode appear to have been united into one great fall. With the increased volume of water at the maximum height of the falls, as at the apex of the modern horseshoe cataract, the recession was very rapid, so that the falls receded to above the railroad bridges in eight hundred years more. It was in the next episode that the descent of the river was reduced from four hundred and twenty feet to three hundred and twenty-six feet, which is that of the present day. These changes of height of falls and volume of the river must not be supposed to have been sudden, and, although they were secular, yet there were long periods of rest, as shown by the landmarks, which are mostly obliterated where they were imperfectly engraved during short epochs of repose. The first stage of the last episode is characterized by the retreat of the falls through the great rocky barrier (Johnson's Ridge, *e e*, Fig. 9) on the northern side of the buried Tonawanda Valley. Beyond this barrier the river speedily removed some ninety feet of drift for a distance of a mile and a half to the head of the rapids above the horseshoe cataract, and the recession across the buried valley has been the last stage of the present episode of the falls. Here the necessary time for the retreat of the falls since passing the railway bridges has been three thousand years.

Adding the duration of the various stages of the river together, the age of the falls is computed at thirty-one thousand years, or of the river thirty-two thousand years. These figures are based upon the severest analytical methods at present attainable, but the discoveries in the physics of the river cover most of the doubtful points; yet in the determination of the amount of work performed in the middle episodes some points are open to revision, but the errors they cover form only a small portion of the life of the cataract, and a little time, more or less, would not greatly change the results given. No general guesses or objections have been found worthy of consideration. The determinations had to be attempted in parts, and the aggregate results have been confirmed by two other sets of investigations: one on the relative amount of tilting of the deserted shores, and the other upon the rate of the rising of the land in the Niagara district, which has been found to be about one foot and a quarter a century, but much more rapidly to the north and east.

NIAGARA FALLS NARROWLY ESCAPED EXTINCTION.—Fifteen hundred years ago the terrestrial movements raised the Johnson barrier to the Erie basin so high that the waters of that lake reached not merely the level of Lake Michigan, but the point of turning all the water of the upper lakes into the Mississippi drainage by way of Chicago. But the falls were then cutting through the ridge, and when this was accomplished, before the change of drainage was completed, the surface of Lake Erie was suddenly lowered by many feet, and thus the falls were re-established for some time longer.

DEATH OF THE FALLS.—Slowly, year by year, one sees the cataract wearing back and suggesting the time when the river will be turned into a series of rapids; but another silent cause is at work, and one not easily seen—namely, the effects of the changing of level of the earth's crust. From the computations already referred to it was found that for the first twenty-four thousand years of the life of the river only the Erie waters flowed by way of the Niagara River, and for only eight thousand years have all the waters of the upper lakes been feeding the falls. If the terrestrial movements continue as at present, and there appears no reason to doubt it, for the continent was formerly vastly higher than now, then in about five thousand years the rim of the Erie basin promises to be raised so high that all the waters of the upper lakes will flow out by way of the Chicago Canal. Thus the duration of Niagara Falls will have continued about thirty-seven thousand years. But the lakes will endure beyond the calculations of the boldest horologist.

RELATION OF THE FALLS TO THE ICE AGE.—In telling of the times of the great mutations in the physical history of the lake region, the story of Niagara Falls seems completed, but as a timepiece they are much more important in being used as a stepping stone back to the great period of frost which separated the former order of the continent from the modern. Having ascertained the approximate amount of the rising of the land recorded in the deserted beaches, before and since the birth of Niagara Falls, and the rate of the rising of the land, and applying it to the movement recorded in the abandoned shores, it is concluded that the epoch when the lake region formed great expansions of more or less open water commenced fifty or sixty thousand years since. Going so far back in time, other conditions may have obtained to vary the rate, but these have been allowed for as far as possible.

Beyond the lake epoch the vicissitudes between the periods of great regional submergence and the earlier high continental elevation of the ice age proper are apparent, but the events are certainly unexplained, for what was done by glacial action and what by waves has not been determined. Niagara Falls

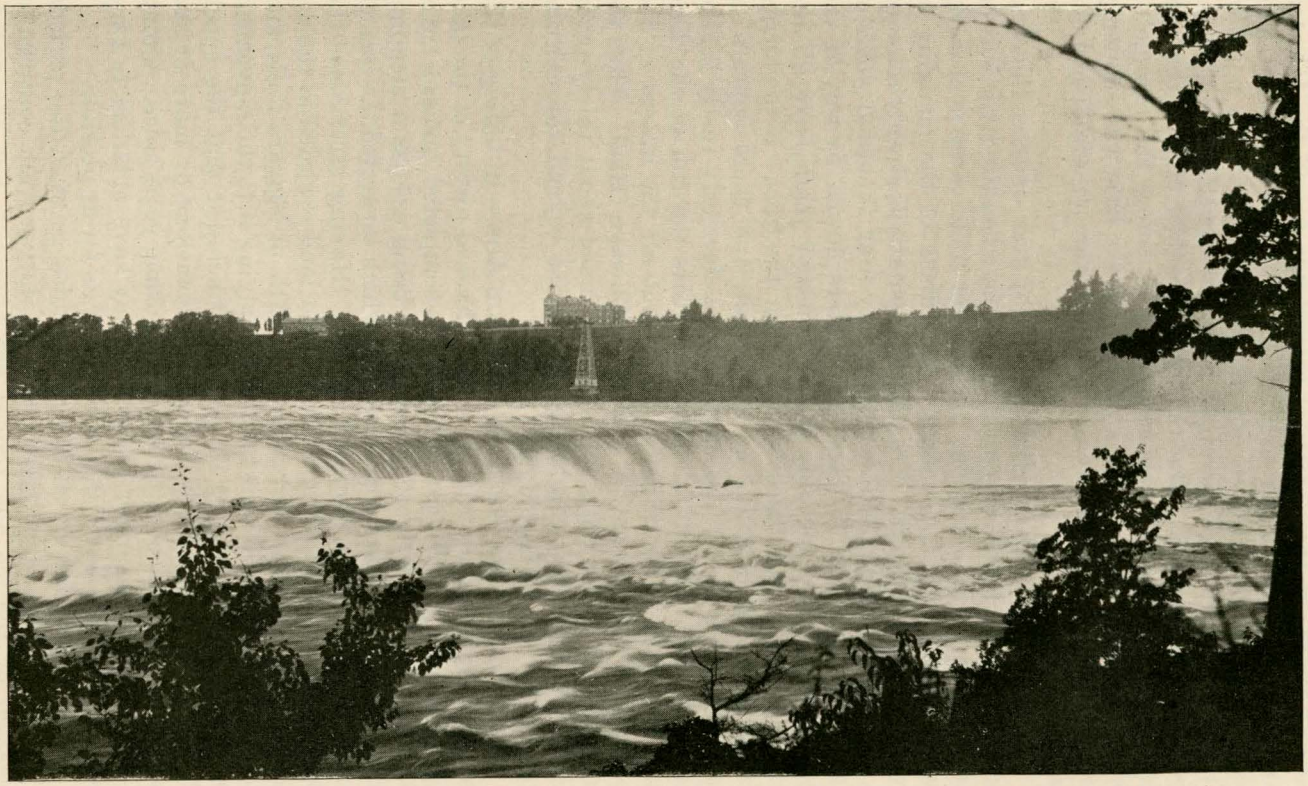

FIG. 17.—VIEW OF RAPIDS ABOVE THE FALLS AND OF HORSESHOE CASCADE; ALSO THE SAND TERRACE AND RIDGE OF TILL ON CANADIAN SIDE.

shows that the end of the Glacial period in the lake region was long ago.

How Niagara Falls may be used to ascertain the Antiquity of Man.—The relation of Niagara Falls to the deserted shores of the lake region and the high terraces is now pretty well known, and the old water margins have been traced over wide areas; but these may be much further extended and their relations to other regions beyond the drainage basins of the Great Lakes be ascertained, so that we may hope that Niagara Falls may be used as a means of at least roughly estimating the age of the deserted river banks on which the oldest inhabitants left their scanty treasures long ago. Concerning this application, it seems as only a question of the work of so many men and so much time.

To the geologist, the birth, life, and death of Niagara Falls show no more rapid changes than come within the limit of modern observations. There have been no sensational catastrophes, although in the popular mind these changes come with new and startling revelations, so that the most conservative observer may be surprised. The changes in the history of Niagara have now been told, so far as we know them. We can still watch the river performing its wonderful amount of work and the slow recession of the falls, as shown in Fig. 17.

If the reader of this sketch of the history of Niagara Falls desires the fuller information upon which this study is based, he is referred to Duration of Niagara Falls and the History of the Great Lakes, by the present writer, whose labors have been brought together by the Commissioners of Niagara Falls Reservation, under the presidency of the Hon. Andrew H. Green, whose liberal policy is not merely to preserve the falls as an international park, but to make known their scientific history.

In the ascension of the balloon Phenix, made from Stassfurt, Prussia, in December, 1894, the weather being misty at starting, the temperature at first increased up to a considerable height, but afterward fell, and at 32,150 feet stood at −20° C. At about 29,500 feet the balloon passed through a veil-like stratum of cirrus clouds, consisting of perfectly formed flakes of snow. At 31,500 feet the thermometer dropped to −54°, and indicated only −11° in the sun's rays. The highest temperature recorded was 43°. During the ascent of three hours and the descent of two hours and twenty minutes the balloon traveled one hundred and eighty-six miles, although it was almost calm at the surface.

Observing the growth of bamboos in the Botanical Garden of Buitenzorg, Java, Mr. Gregory Kraus noticed one plant which added to its length 22·9 centimetres a day for fifty-eight days. Another plant grew 19·9 centimetres, and a third nineteen centimetres a day for sixty days. The longest single day's growth observed was 42·45 centimetres.